

7. CONCLUSION

Several major studies were performed to evaluate the effect of UWB signals on GPS receiver performance. These studies characterized the UWB signals, compared conducted and radiated UWB signals, and evaluated effects of the UWB interference on GPS receiver operation (i.e. locking) and “observables.”

The GPS signal was generated by a GPS constellation simulator. A select group of UWB signals were generated with a programable arbitrary waveform generator and custom hardware which triggered a sequence of UWB pulses. Signals with uniform pulse spacing (UPS), on-off-keying (OOK), 2% relative reference dithering (RRD), and 50% absolute reference dithering (ARD) signals at 0.1, 1.0, 5.0, and 20.0 MHz pulse repetition frequencies (PRF) were used. These signals could also be gated to imitate the bursty nature of some UWB devices. Various combinations of signals were at times combined to simulate interference from multiple UWB devices.

The UWB signals were sampled and characterized with the amplitude probability distribution (APD) in hopes that APD features (i.e., constant amplitude, Gaussian noise, and impulsive noise) can be correlated to GPS receiver performance degradation. In addition, although under usual conditions, radiated UWB and GPS signals are combined at the antenna, this study uses conducted signals to maximize control and repeatability of experimental conditions. A comparison of radiated and conducted UWB-signal APDs and waveforms showed that systematic errors were not introduced by the conducted approach.

Two independent operational tests, break lock (BL) and reacquisition time (RQT), measured the receiver’s ability to maintain and reacquire lock over a range of UWB signal powers. The BL and RQT metrics bracket a region of GPS receiver performance degradation. The RQT determines the lower bound where the interference begins to have a detrimental effect on the operation of the receiver. The BL point sets the upper bound where operation is impossible.

The observational test, conducted in parallel with the BL test, retrieved “observable” measurements made by the GPS receiver to estimate performance degradation. Pseudorange and carrier phase measurements were used to determine various range estimates that were compared to simulated ranges in order to evaluate the effects of UWB interference. Cycle slip indication and signal-to-noise ratio measurements evaluate the receivers ability to detect interference and make decisions regarding GPS measurement integrity.

The BL point varied most with the type of receiver. The semi-codeless receiver broke lock with the first indication of cycle slip conditions. The general purpose navigation receiver continued operation with frequent indications of cycle slip conditions. RQT was found to be the most sensitive metric. In many cases RQT showed increases without attendant degradations in range error or increases in frequency of cycle-slip conditions. RQT, range error, and cycle slip condition indicators generally show a gradual degradation as UWB signal power is increased.

This shows that the strength of the measurement methodology lies not in a single result but in the total picture painted by the combined results.

UPS and OOK signals have discrete spectral lines. Time-varying Doppler shift due to satellite motion inevitably causes these lines to interfere with GPS discrete spectral lines. These test results show that observables degrade at low UWB signal powers as the lines approach and recede. Line interference becomes more severe as PRF increases.

APDs of sampled 50%-ARD and 2%-RRD signals approach that of Gaussian noise as PRF increases. Consequently, for high-PRF dithered signals, interference effects resemble that of Gaussian noise. In general, low-PRF dithered signals generate more impulsive interference which is more benign than Gaussian noise.